Improved RF Calibration Techniques: Commercial Precision IF Attenuator Evaluation

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The IF attenuator normally used for system noise temperature calibrations is the largest single contributor to measurement inaccuracy. Various IF attenuators have been evaluated and calibrated using a National Bureau of Standards IF precision standard. Measurement techniques are indicated and results given. It is noted that there is a wide spread in the accuracy among various manufacturers and also in the same model type from a particular manufacturer. Excessive use appears to be an important factor in accuracy degradation.

I. Introduction

An analysis of low-noise receiving system operating noise temperature calibrations using the Y-factor technique has shown that the single largest source of calibration error is presently due to the IF attenuator (Ref. 1). Various commercial IF attenuators have been evaluated to determine actual performance and to select the unit with the greatest repeatability and accuracy. In addition, units with sufficient repeatability can actually be calibrated with a laboratory standard to a greater accuracy than normally available.

II. System Description and Performance

Figure 1 shows a block diagram of the laboratory calibration system. The laboratory standard attenuator (Fig. 2) was purchased from the National Bureau of Standards and has an accuracy of 0.005/10 dB and a repeatability of approximately 0.0005 dB at 50 MHz. It was necessary to take particular care with the calibration system to obtain maximum stability. Coaxial hard line and shielding were used throughout so as to minimize loss of accuracy due to leakage. Particular care was taken to clean and tighten the coaxial connectors. Shielding was verified by the use of a high-level radiating probe. The strip-chart recorder was helpful in providing a null set point and recording system stability. Figure 3 shows a recording of typical system stability.

III. Measurement Technique

Although the basic measurement is quite straightforward, extreme care must be taken to ensure that leakage and drift do not corrupt the results. The problem of backlash is minimized in the test attenuator by always approaching the setting carefully from the same direction. The standard attenuator has an optical readout.

The actual measurements are made by first observing a null point on the strip-chart recorder and then changing the attenuator under test by the indicated amount from the reference setting. The standard attenuator is then changed by the amount necessary to bring the power at the detector back to its initial null point as indicated on the strip-chart recorder. The calibrated attenuation difference (dB) in the test attenuator is then equal to the attenuation difference (dB) in the standard attenuator. The error in the test attenuator is defined as the magnitude of the attenuation difference (dB) in the standard attenuator minus the magnitude of the attenuation difference (dB) in the test attenuator:

$$\text{error} = |\Delta_{std}| - |\Delta_{test}|$$

After each measured attenuator difference (dB), both attenuators are returned to their original reference null points so as to minimize the effects of drift in the signal source and the detector. Measurement and attenuator repeatability are verified by repeated runs.

IV. Results

Many attenuators from a number of manufacturers were tested. The results of these tests are plotted in Figs. 4–6 showing the average of a number of measurement sets and the peak-to-peak deviations at each attenuator setting. Figure 4 indicates the performance for a unit that had long field use and relative poor performance ($>$ 0.02 dB pk/pk). Figure 5 indicates the performance of another unit manufactured with considerably better performance than the units presently in use. Figure 6 shows the results of calibrations of typical attenuators with various amounts of service. A three-digit RF Techniques number (RFT XXX) is used to identify the unit tested. This is done because of the large difference in accuracy and repeatability even among units of the same make and model.

V. Conclusions

Waveguide-beyond-cutoff piston IF attenuators are useful devices when one requires a continuously variable means of changing the level of a signal. However, if one must know the change to a high degree of accuracy, then one must carefully select a unit that will meet that required repeatability and precision. There is a wide spread in performance of these attenuators among various manufacturers and also in the same model from a particular manufacturer. Excessive use is probably an important factor in performance degradation.

Reference

1. C. T. Stelzried, "Operating Noise-Temperature Calibrations of Low-Noise Receiving Systems," *Microwave Journal*, Vol. 14, No. 6, June 1971, p. 41.

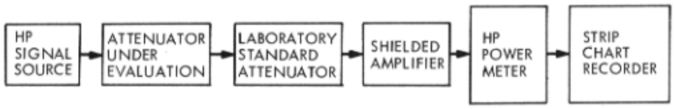


Fig. 1. Block diagram of IF attenuator calibration system

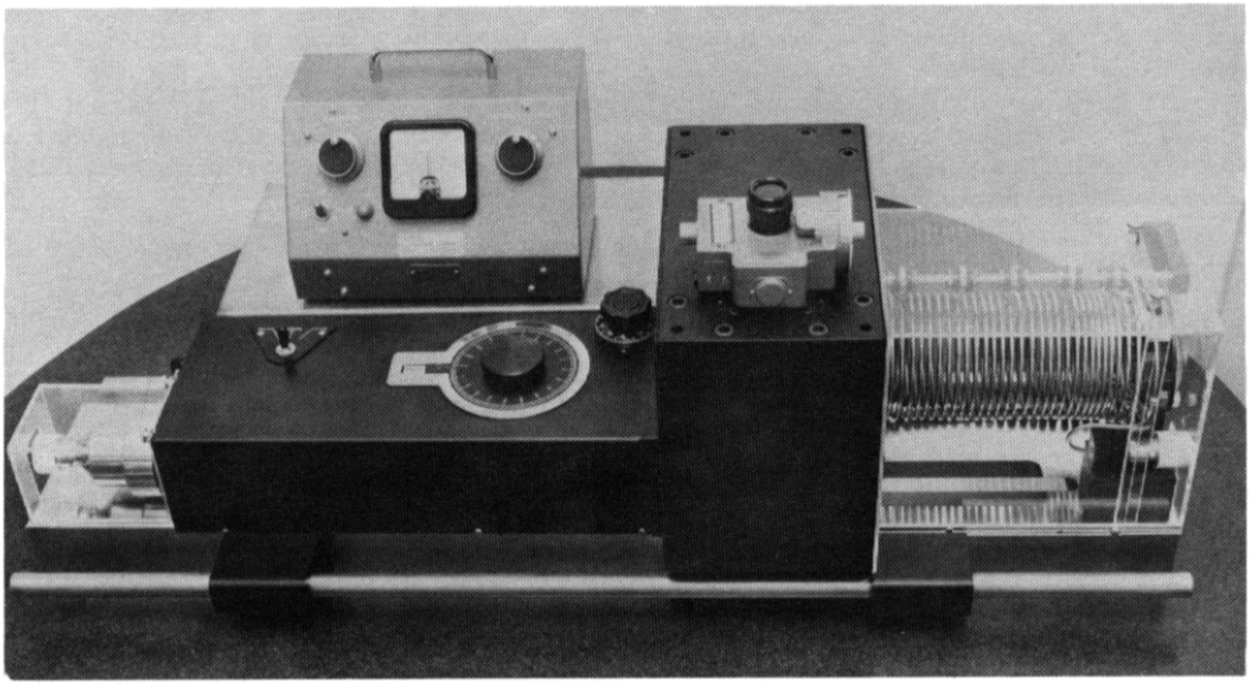


Fig. 2. Photograph of laboratory IF standard attenuator

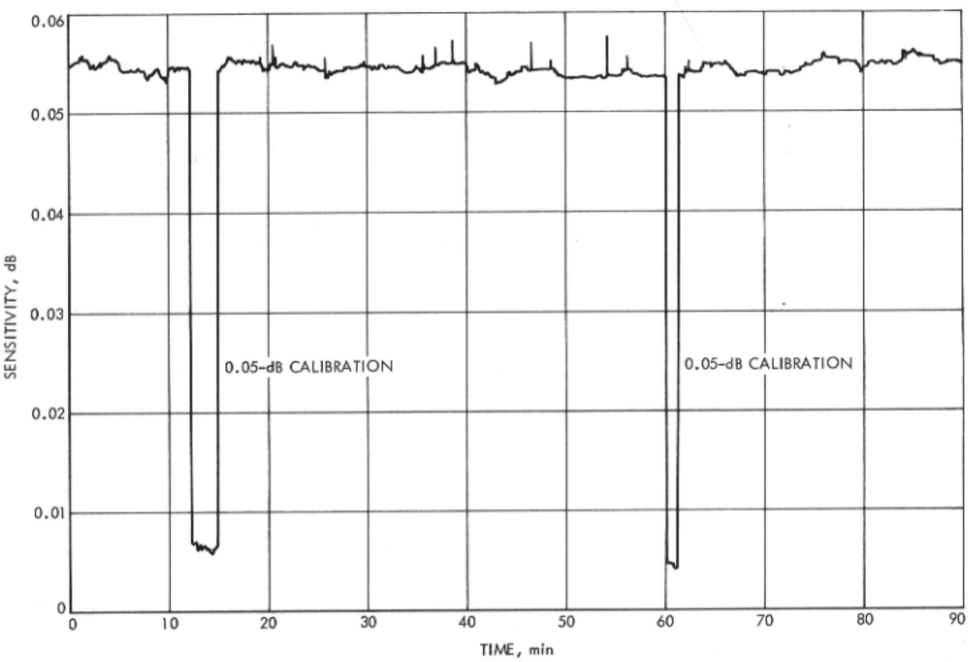


Fig. 3. Typical recording of IF attenuator calibration system stability

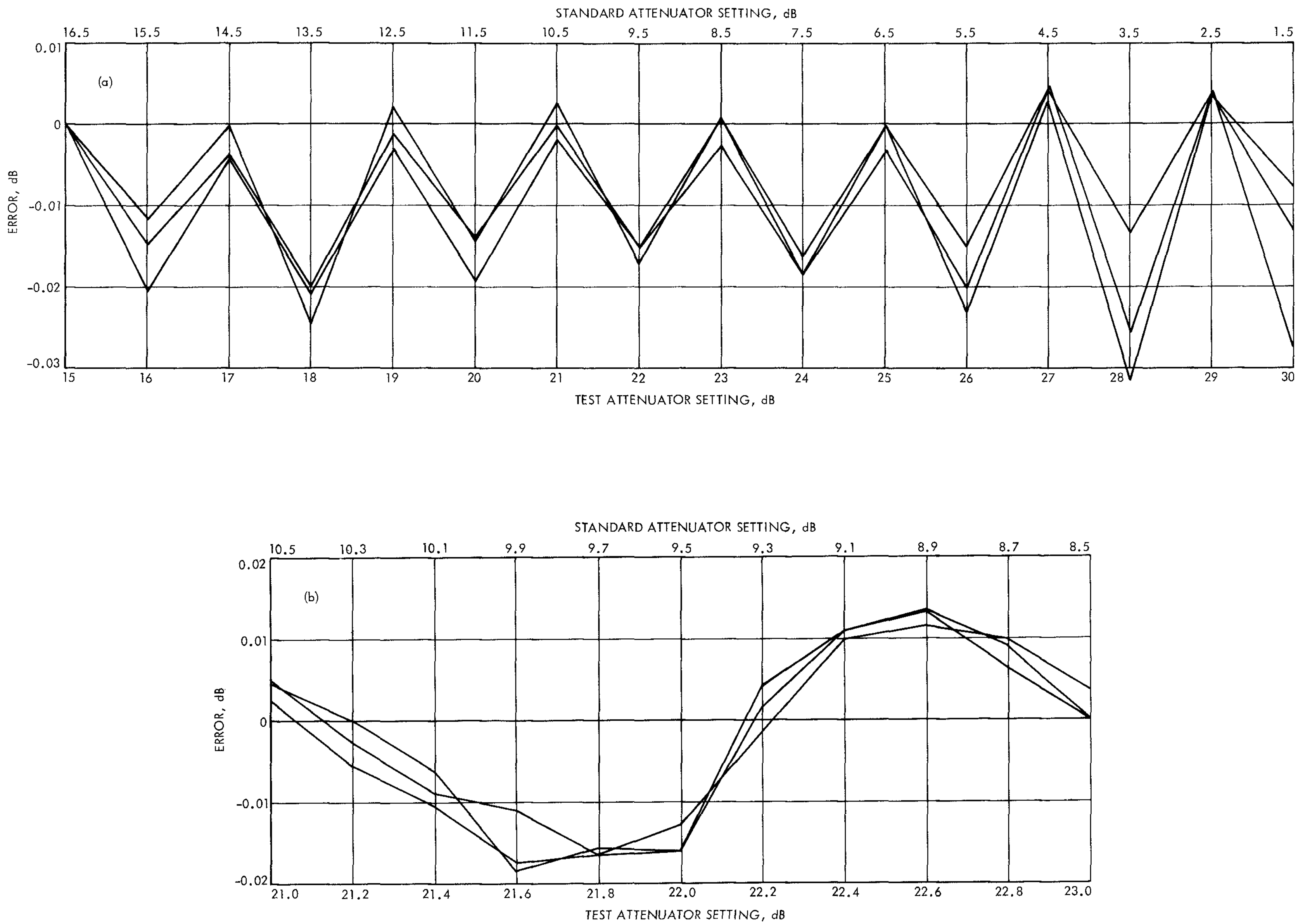


Fig. 4. Results of calibration of a heavily used attenuator: (a) RFT 483, 15-dB range, 1-dB steps, (b) RFT 483, 2-dB range, 0.02-dB steps

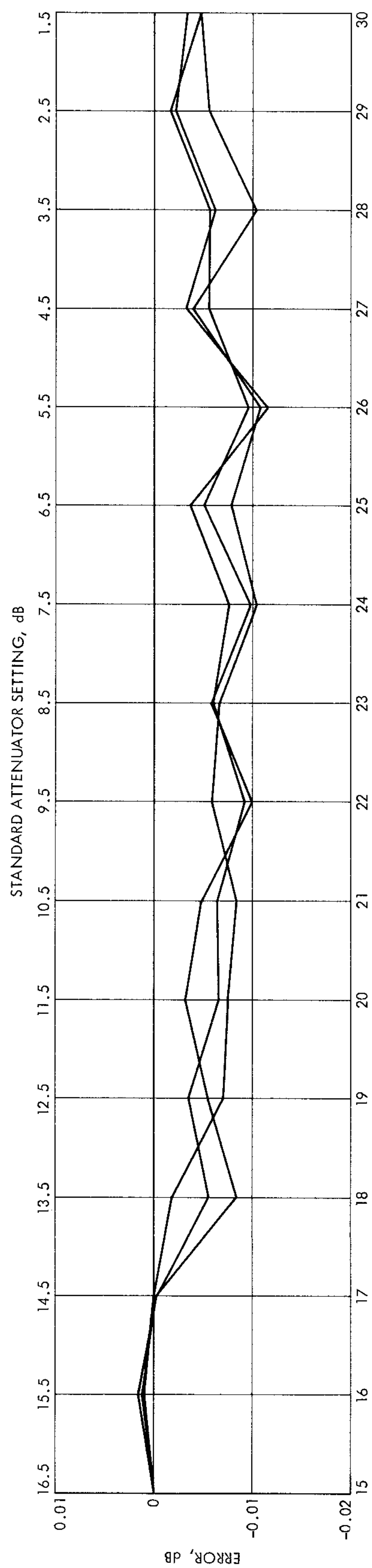


Fig. 5. Results of calibration of an atypical new attenuator (RFT 502, 15-dB range, 1-dB steps)

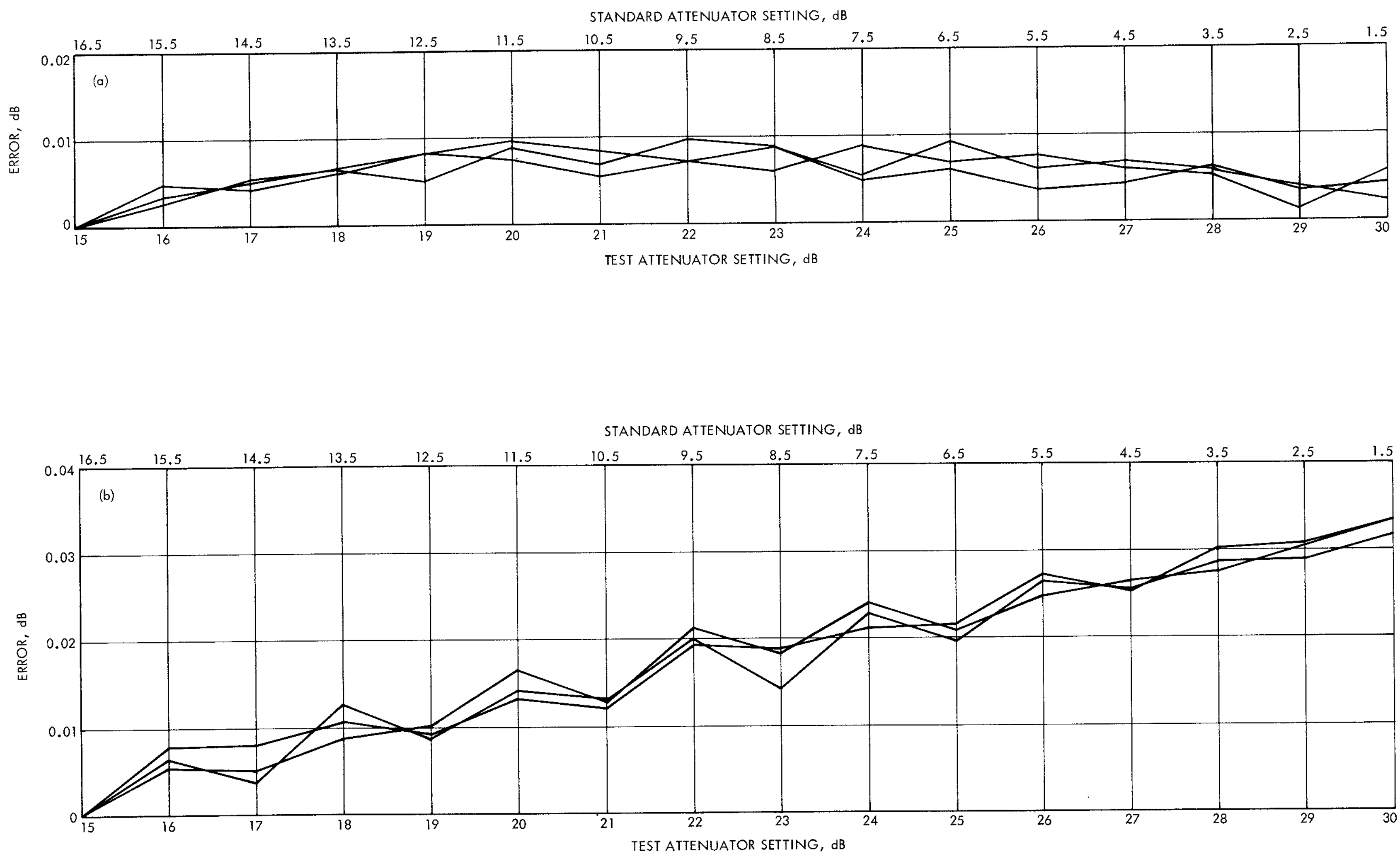
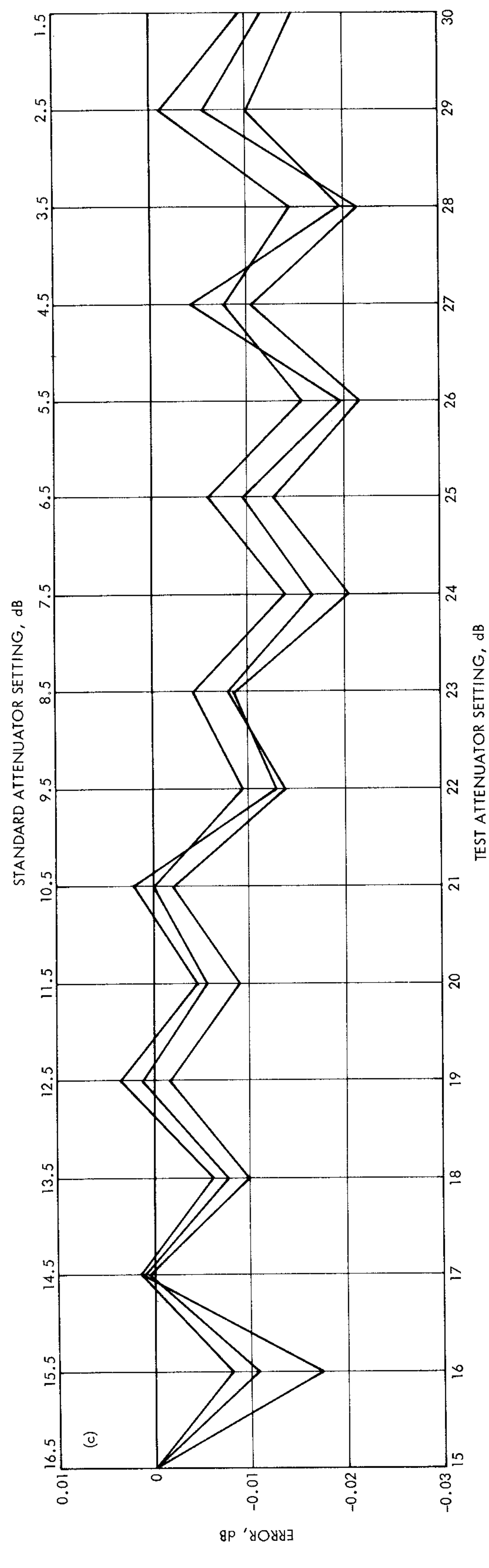
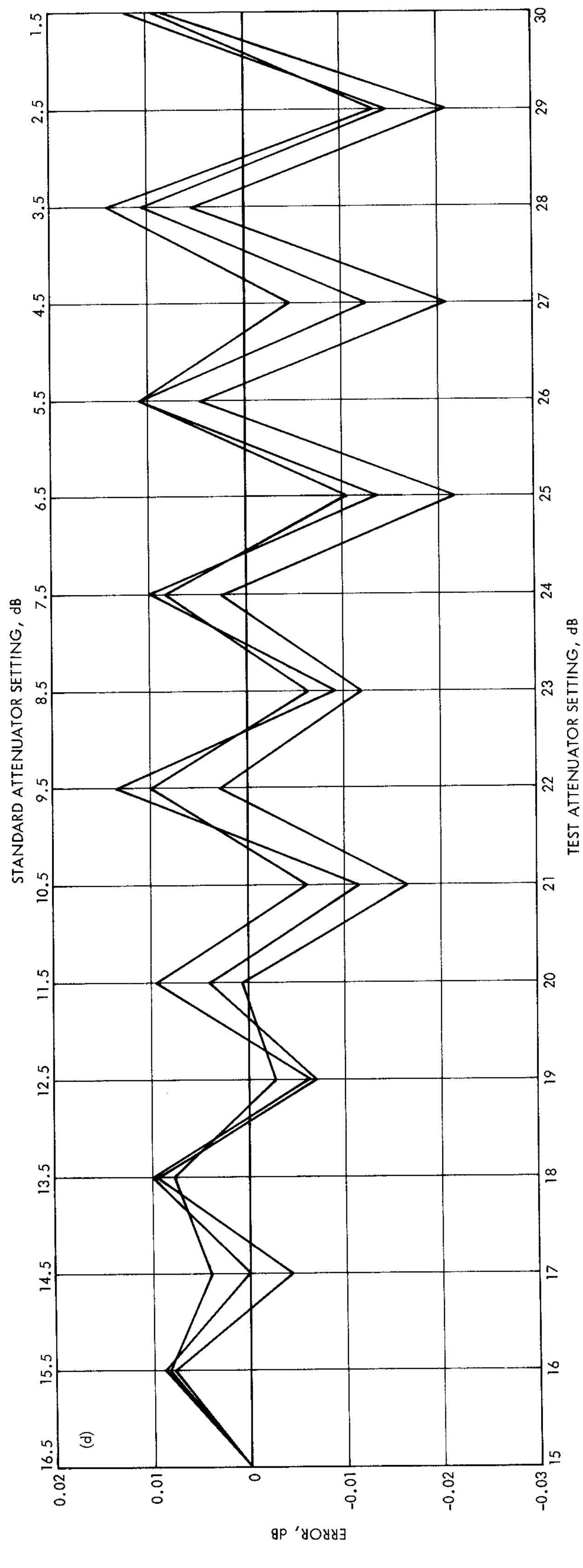


Fig. 6. Results of calibrations of a number of typical attenuators (data at 50 MHz): (a) RFT 485, 15-dB range, 1-dB steps, (b) RFT 487, 15-dB range, 1-dB steps, (c) RFT 496, 15-dB range, 1-dB steps, (d) RFT 497, 15-dB range, 1-dB steps, (e) RFT 498, 15-dB range, 1-dB steps, (f) RFT 490, 15-dB range, 0.5-dB steps, (g) RFT 490, 15-dB range, 1-dB steps, (h) RFT 499, 15-dB range, 1-dB steps

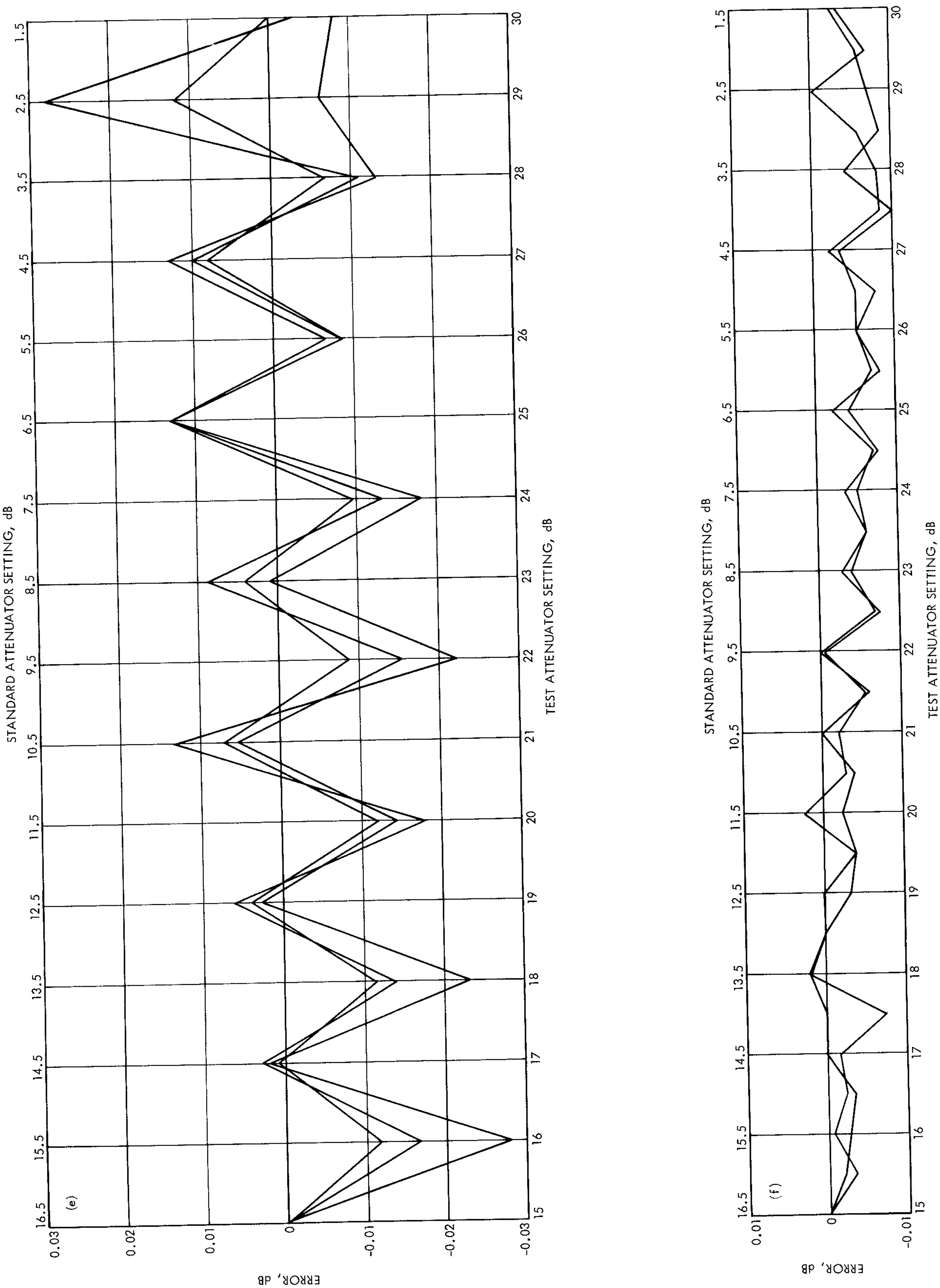


(c)
STANDARD ATTENUATOR SETTING, dB
16.5
15.5
14.5
13.5
12.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
TEST ATTENUATOR SETTING, dB
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
ERROR, dB
0.01
0
-0.01
-0.02
-0.03



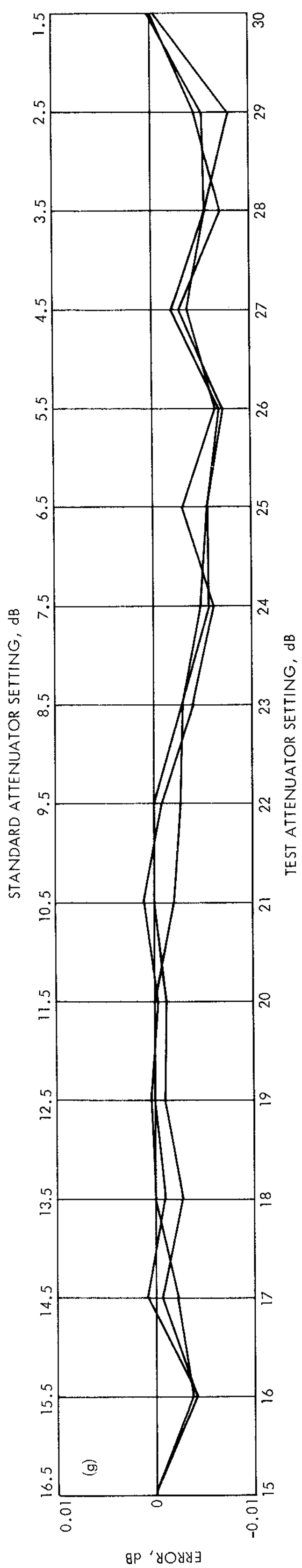
(d)
STANDARD ATTENUATOR SETTING, dB
16.5
15.5
14.5
13.5
12.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
TEST ATTENUATOR SETTING, dB
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
ERROR, dB
0.02
0.01
0
-0.01
-0.02
-0.03

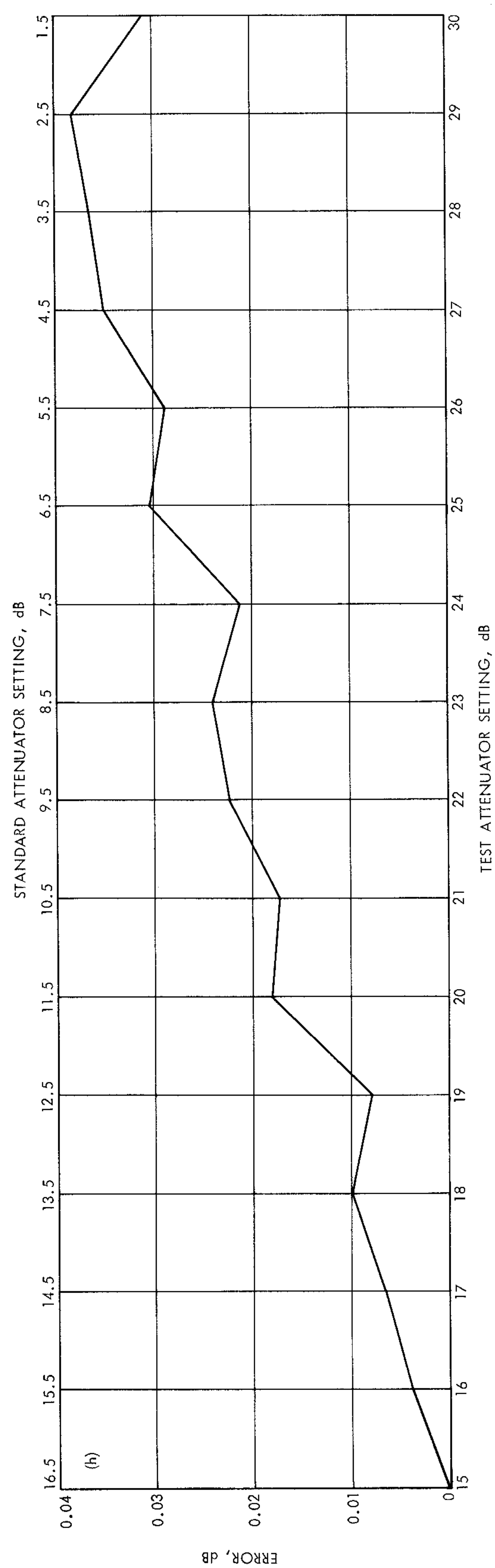
Fig. 6. (contd)



(e)
STANDARD ATTENUATOR SETTING, dB
16.5 15.5 14.5 13.5 12.5 11.5 10.5 9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5
TEST ATTENUATOR SETTING, dB
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
ERROR, dB
0.03 0.02 0.01 0 -0.01 -0.02 -0.03
(f)
STANDARD ATTENUATOR SETTING, dB
16.5 15.5 14.5 13.5 12.5 11.5 10.5 9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5
TEST ATTENUATOR SETTING, dB
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
ERROR, dB
0.01 0 -0.01

Fig. 6. (contd)


(g)
STANDARD ATTENUATOR SETTING, dB
TEST ATTENUATOR SETTING, dB
ERROR, dB
0.01
0
-0.01
1.5
2.5
3.5
4.5
5.5
6.5
7.5
8.5
9.5
10.5
11.5
12.5
13.5
14.5
15.5
16.5
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15


(h)
STANDARD ATTENUATOR SETTING, dB
TEST ATTENUATOR SETTING, dB
ERROR, dB
0.04
0.03
0.02
0.01
0
1.5
2.5
3.5
4.5
5.5
6.5
7.5
8.5
9.5
10.5
11.5
12.5
13.5
14.5
15.5
16.5
30
29
28
27
26
25
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19
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17
16
15

Fig. 6. (contd)